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carcasses of some huge whales brought in to land since his departure.

The moon rose full and round, but waned rapidly as she neared the zenith. A fine eclipse took place which was almost total. Crowds gathered on the shore to watch the moon's fading light. The *Americano* ought to be able to explain it. He is applied to. Whereupon, by the light of an antique oil-lamp in a store near by, with a big earthen water-jar to personate the earth, and a smaller one the moon, a lecture on the theory of eclipses was delivered to an appreciative audience, with heaven's blue dome for a chart.

Next day a few hundred weight of whales' bones were added to our freight, and we moved up stream. The tiled roofs and white walls and cocoa palms of Caravellas came in view, Jaco blew his horn, and, in a few moments, with the rattle of the chain from the bow, the Cruise of the "Abrolhos" had ended.

# NOBERT'S TEST PLATE AND MODERN MICROSCOPES.

BY CHARLES STODDER.

EVERY possessor of a first-class microscope wishes to know what his instrument is capable of doing. To the practical worker it is a matter of much importance, for when the utmost power of his instrument is exhausted, he will know that it is a waste of time to endeavor to see more. One of the desirable and important properties of a microscope is the power to show or "resolve" very fine lines grouped together, e. g. the striation of the frustules* of the diatomaceæ. For the purpose of testing the resolving power of the microscope, the lines ruled on glass by F. A. Nobert, of Barth,

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*A frustule (*L. frustrum*, a fragment) is one of the fragments into which diatoms separate.

Pomerania, have long been admitted by experts as the best known test, not only in consequence of their exceeding fineness, but also because they are ruled to a known scale, and because they are so close that physicists have asserted that it is impossible that they ever can be seen, Nobert himself being in this category; and all trials of these plates, except those to be herein mentioned, have resulted in failures to resolve the finer lines of these plates.

The Nobert test is a series of groups of parallel lines ruled on glass thus ||||||| ||||||, each succeeding group being finer than the preceding one. Different plates have a different number of groups, ruled to different scales. The one used by Messrs. Sullivant and Wormly (American Journal of Science, 1861) has thirty bands or groups, the coarsest having its lines $\frac{1}{1000}$ of a Paris line apart, and the finest being $\frac{1}{8000}$; each group or band being about $\frac{1}{2000}$ of an English inch in width, and the whole thirty occupying a space perhaps a little more than $\frac{1}{50}$ of an inch. Now it is a difficult matter for the mind to appreciate such minute divisions of space, yet it is essential, in order to estimate a little the difficulty of seeing such lines, to form some idea of their minuteness. The average diameter of a human hair is about $\frac{1}{1000}$ of an inch, yet in a space only one half as great in the coarsest band of the Nobert plate there are seven lines, while in the 30th band there are forty-five.

The plate which I have used in the trials to be detailed was made in 1863. It has nineteen bands, the first being ruled to $\frac{1}{1000}$ of a Paris line, and each band increasing by five hundred, so that the 19th is $\frac{1}{10000}$.

The following table gives in the second column the fractional part of a Paris line* between the lines of each band; the third column, the decimal part of a line as marked on the plate by Nobert; the fourth, the number of lines to an English inch; the fifth, the number of the band in a thirty-band plate corresponding in fineness.

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* One Paris line = .088815 of the English inch.

| | Paris line. | Decimal of Paris line. | Lines to English inch. | Corresponding No. of Sullivant and Wormly's plate. |
|---|---|---|---|---|
| 1. | 1-1000 | .1001 | 11,240 | 1st |
| 2. | 1-1500 | .000633 | | |
| 3. | 1-2000 | .0005 | 22,480 | |
| 4. | 1-2500 | .0004 | | |
| 5. | 1-3000 | .000333 | | |
| 6. | 1-3500 | | | |
| 7. | 1-4000 | .00025 | 44,960 | |
| 8. | 1-4500 | | | |
| 9. | 1-5000 | .0002 | 56,200 | 15th |
| 10. | 1-5500 | | | |
| 11. | 1-6000 | .000167 | 67,622 | 20th |
| 12. | 1-6500 | | | |
| 13. | 1-7000 | .000143 | 78,737 | 25th |
| 14. | 1-7500 | | 84,400 | |
| 15. | 1-8000 | .000125 | 90,074 | 30th |
| 16. | 1-8500 | .000117 | 96,234 | |
| 17. | 1-9000 | .000111 | 101,434 | |
| 18. | 1-9500 | .000105 | 107,167 | |
| 19. | 1-10000 | .000100 | 112,668 | |

Has human art ever made an instrument capable of rendering lines, 112,000 to an inch, visible? If not, is it possible to do so? Is there anything in the laws of light, which renders it impossible to see lines so close, and therefore render useless the labors of the optician to improve his instruments beyond a certain point? and, as a corollary, is it decided that it will be useless for the naturalist to try to investigate the structure of tissues beyond what the best existing instruments have shown? It must be borne in mind that the power of seeing a single object is not the question, but the power of distinguishing two or more objects nearly in contact. The problem is exactly the parallel of that of the power of the telescope of separating double stars. A brief sketch of what has been done, and what opinions on the problem have been expressed by eminent microscopists and opticians is essential to a full understanding of the question.

Professor Quecket, in 1855, asserted that "no achromatic has yet been made capable of separating lines closer together than the $\frac{1}{75000}$ of an inch." "Mr. Ross found it impossible to ascertain the position of a line nearer than $\frac{1}{80000}$ of an inch." "Mr. De la Rue was unable to resolve any lines on Nobert's test plate closer than $\frac{1}{81000}$ of an inch."

Dr. William B. Carpenter, in his work on the Microscope, published in 1856, says, "Even the $\frac{1}{12}$ objective will probably not enable any band to be distinctly resolved, whose lines are closer than $\frac{1}{79000}$ of an inch. At present, therefore, the existence of lines finer than this is a matter of faith rather than of sight; but there can be no reasonable doubt that the lines do exist, and the resolution of them would evince the extraordinary superiority of any objective, or of any system of illumination which should enable them to be distinguished." In his second edition issued in 1859, Dr. Carpenter repeated the same remarks, but substituted $\frac{1}{85000}$ for $\frac{1}{79000}$, and then added, "There is good reason to believe that the limit of perfection (in the objective) has now been nearly reached, since everything which seems theoretically possible has been actually accomplished." In the third edition, 1862, he again alters the figures to $\frac{1}{84000}$, but adds nothing more.

On the other side the late Professor J. W. Bailey claimed to have seen lines as close together as $\frac{1}{100000}$ to the inch, and Messrs. Harrison and Solitt, of Hull, England, claimed to have measured lines on the diatom *Amphipleura pellucida*, as fine as 120,000 to 130,000 to the inch, and expressed the opinion that lines as fine as 175,000 might be seen with proper means.

To determine if possible the truth between these conflicting opinions, Messrs. Sullivant and Wormley (American Journal of Science, January, 1861) made an exhaustive trial of one of these "marvels of art." They state that the optical apparatus at their command was ample; it included a "Tolles' $\frac{1}{30}$ objective of 160° angular aperture,—an objective of rare excellence in all respects,—besides $\frac{1}{12}$ and $\frac{1}{16}$ objectives of other eminent opticians." They were able to obtain an amplification of 6,000 diameters. The plate contained thirty bands, as previously mentioned.

> "Up to the 26th band ($\frac{1}{78100}$) there was no serious difficulty in resolving and ascertaining the position of the lines; but on this and the

subsequent ones, spectral lines, that is, lines composed of two or more real lines, more or less prevailed, showing that the resolving power of the objective was approaching its limit. By a suitable arrangement, however, of the illumination, these spurious lines were separated into the ultimate ones on the whole of the 26th, and very nearly on the whole of the 27th band ($\frac{1}{81213}$); but on the 28th, and still more on the 29th, they so prevailed, that at no one focal adjustment could more than a portion of the width of these bands be resolved into the true lines. The true lines of the 30th band we were unable to see, at least with any degree of certainty."

"These experiments induce us to believe that the limit of the resolvability of lines, in the present state of the objective, is wellnigh established," and they draw the conclusion, "that lines on the Nobert's test plate, closer together than about $\frac{1}{78000}$ of an inch, cannot be separated by the modern objective."

Although the paper of Messrs. Sullivant and Wormley was republished in the Quarterly Journal of Microscopical Science, in London, and might be considered as being a challenge to the opticians and microscopists of Europe to show what they could do in resolving the test plate, yet no report can be found of any attempts to resolve the lines until 1865, when Max Schultz (Quarterly Journal of Microscopical Society, January, 1866) described the Nobert plate of nineteen bands, and gave the results of his trials for resolving them. "The highest set he has been able to define with *central* illumination is the 9th, which is resolved with Hartnack's immersion No. 10, and Merz's immersion system $\frac{1}{24}$. With *oblique* illumination he has not been able with any combination to get beyond the 15th." It will be seen by reference to the table that Schultz saw finer lines than Sullivant and Wormley. This is the only report we can find in print from Europe.

In this country we find no published results; but Mr. R. C. Greenleaf, of Boston, and the writer were well satisfied that they saw the lines 90,000 to the inch with a Tolles' $\frac{1}{5}$ in 1863, and the next year Mr. Greenleaf saw the same lines, unmistakably, with a Tolles' $\frac{1}{12}$. Dr. J. J. Woodward, of Washington, in a communication to the Quarterly Journal of Microscopical Science, London, October, 1867, p.

253, states that with monochromatic light, and Powell and Lealand's $\frac{1}{50}$, $\frac{1}{25}$, and $\frac{1}{16}$ objectives, a Hartnack immersion, No. 11, and a Wales $\frac{1}{8}$, with amplifier, he satisfactorily resolved the 29th and 30th bands of Nobert's test plate. In a letter to the writer written since, Dr. Woodward informs me that the plate used was the *same one* used by Sullivant and Wormley, as the 30th band was the finest on that; the result did not show that finer lines could not be seen. Dr. Woodward informs me, that, since writing that paper, he has received a Nobert plate with the nineteen bands, and that the covering glass was too thick for the $\frac{1}{50}$ objective, but with all the others he was able to resolve the 17th band (101,000 to the inch); the 18th and 19th he was unable to resolve. Dr. Woodward has sent to me a photograph of the 16th, 17th, 18th, and 19th bands, taken by Dr. Curtis with the Powell and Leland $\frac{1}{25}$. In the photograph, the lines of the 16th and 17th bands may be counted with some difficulty, but if the whole band is copied, or if the bands are of the width of $\frac{1}{2000}$ of an inch, there are not lines enough. The lines of the 18th and 19th bands cannot be counted in the photograph. From this it will be noticed that Dr. Woodward has resolved *finer lines* than any other observer had yet seen, so far as report gives us any information.

My esteemed correspondent, M. Th. Eulenstien, of Stutgard, Wirtemberg, writes to me, under date of Dec. 17th, 1867, "I have myself resolved the 14th band with a $\frac{1}{12}$ Powell and Lealand, and also, but less unmistakably, with No. 11 Hartnack's immersion, with oblique light." "Nobert himself has never seen with his highest powers higher than the 14th." "This will show you the continental state of affairs." Mr. R. C. Greenleaf and myself have lately tried several objectives, and the result is appended below:*

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| *Wales' 1-5 ang. ap., 140°, B eye-piece, power 475 dia., sunlight oblique, . . | 8th band. |
| Hartnack's immersion No. 10=1-14, ang. ap. 155°, power 1062, B eye-piece, light oblique, . . . . . . . . . . . . . . . . . . . . . . . . | 10th " |
| Nachet's immersion No. 6 = 1-12, B eye-piece, sunlight oblique, . . . . . | 8th " |
| " " No. 10=1-21, B eye-piece, sunlight central, . . . . . | 9th " |

With Tolles' $\frac{1}{6}$ immersion, angular aperture 170°, B eyepiece, power 550, Mr. Greenleaf and myself both saw the 19th band satisfactorily. Thus being probably the first ever to see lines of 112,000 to the inch, and establishing the fact of the visibility of such lines, contrary to the theory of the physicists. (It should, however, have been mentioned in the proper place that Mr. Eulenstien says that Nachet claims to have seen them by sunlight recently, which claim needs some confirmation, as his No. 10 failed so completely in my hands.

In the present month (January, 1868), Dr. F. A. P. Barnard writes to Mr. Greenleaf, that he had tried several objectives, naming a Spencer $\frac{1}{20}$ and $\frac{1}{12}$, a Tolles' $\frac{1}{10}$ and $\frac{1}{3}$, a Wales $\frac{1}{4}$, and a Nachet immersion No. 8, equal to a $\frac{1}{15}$. "The Spencer $\frac{1}{20}$, and the Natchet $\frac{1}{15}$ broke down at about the 11th or 12th band. With the Wales $\frac{1}{4}$ I got as far as ten, or perhaps eleven bands. With the Tolles' $\frac{1}{3}$ I made out distinctly ten."

In another communication he says, "the highest band I can count is the 16th." In a more recent letter to the writer, Dr. Barnard gives the count of the lines on a portion of his plate,—corresponding as nearly as could be expected to figures given in the table up to the 14th; but the 16th band he could not count satisfactorily, different attempts giving varying results. It has been said that the resolution of the lines to the eye implies the ability to count them, but this I think is a fallacy; a few lines of a group may be counted correctly, and then it becomes difficult to identify the line last counted and the one to be counted next. Let any one try to count the pickets in a fence, when the pickets are distinctly visible, say at a distance of 100, or 150 yards,

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|---|---|
| Nachet's immersion No. 10 = 1-21, B eye-piece, sunlight oblique, . . . . | 12th band. |
| Tolles' immersion 1-10, ang. ap. about 160°, B eye-piece, power about 800, sunlight central, . . . . . . . . . . . . . . . . . . . . . . . | 8th " |
| Tolles' immersion 1-10, ang. ap. about 160°, B eye-piece, power about 800, sunlight oblique, . . . . . . . . . . . . . . . . . . . . . . . | 12th " |
| Tolles' immersion 1-10, ang. ap. about 160°, B eye-piece, Petroleum, light oblique, . . . . . . . . . . . . . . . . . . . . . . . . | 12th " |
| Tolles' immersion 1-10, on another occasion I saw the . . . . . . . . . | 15th " |

he will find this difficulty almost insurmountable. In the microscope the micrometer is an aid in counting, but in counting lines of such exquisite fineness, either the micrometer or the stage must be moved, and it is next to impossible to construct apparatus that can be moved at once $\frac{1}{100000}$ of an inch and no more. It would require the genius and skill of Nobert himself to do it.

These trials show conclusively, that it is not the great power of the objective that is important (for in many of the trials here reported the lower powers have given the best results, and the Tolles' $\frac{1}{6}$ immersion the best on record), but it is the skill of the optician in making the instrument. I have since tried the Wales' objective *dry*, and resolved the 13th band well,—thus doing what Mr. G. did with it in water; the inference must be that Mr. G. did not obtain its best work.

NOTE.—Since the foregoing was written, Dr. Barnard has made more trials, and I am well satisfied that he has seen the 19th band with a Spencer $\frac{1}{12}$ and Tolles' $\frac{1}{5}$, *both dry objectives*. This performance fairly surpasses any thing yet done, either in this country or Europe. Dr. Barnard writes (Jan. 29), that he found that the counting of the lines was attended with the very difficulties referred to above, in addition to which there is another trouble, the whole width of a band is not in perfect focus at once; this necessitates a slight change of focal adjustment, and any change renders it extremely difficult to fix, even with the cobweb micrometer, the exact line last counted. He made five counts of the 19th band with the $\frac{1}{12}$, namely:—

| | | | | | |
|---|---|---|---|---|---|
| 1. | 110,392 | to the English inch. | 4. | 106.226 | to the English inch. |
| 2. | 108,270 | " " | 5. | 115,474 | " " |
| 3. | 113,737 | " " | mean, | 110,820 | " " |

The number, according to Nobert, is 112,668. He counts for the 15th 91,545, Nobert, 90,074. Though there is apparently considerable discrepancy between the count and Nobert's figures, yet I consider it as near as can be reasonably expected when all the difficulties are appreciated. Besides, it must be remembered that Dr. Barnard gives as above the number of lines to an inch, not the number actually counted. The actual number in the 19th band should be 56.5, if the band is *exactly* $\frac{1}{2000}$ of an inch, a variation of two lines each way covers the extremes of his counting.

Mr. Greenleaf has just tried (February 7th) an immersion objective by Wales' $\frac{1}{15}$. He resolved the 10th, 11th, and 12th bands perfectly; the 13th was doubtful. Another trial of the Hartnack No. 10 resolved the 13th band perfectly, — the 14th doubtfully.

English and American opticians name their objectives (*i. e.*, the lens or lenses placed next the object, that next the eye being the eye-piece), from their magnifying power, — thus a ¼ inch objective has the same power as a simple lens of ¼ inch focus. Continental European makers generally distinguish their instruments by numbers; the higher numbers indicating higher powers; but as each maker has his own system, the actual power of an instrument must be ascertained by trial. Instruments also often differ from their names, and they cannot generally be depended on. The theoretical power of a microscope is measured from an arbitrary standard of ten inches, — thus, a one inch is said to magnify ten diameters; a ¼ inch, forty diameters. If the standard is taken at five inches, as it is by some, then the "power" is but one half as much. The "power" of the *microscope* is that of the objective multiplied by that of the eye-piece; if the objective magnifies ten diameters, and the eye-piece ten, the result is one hundred diameters.

*Angular aperture* is the angle in the surface of the front lens, at which light will enter the objective, — the greater the angular aperture, the more light, and usually the greater *resolving* power.

An *amplifier* is an achromatic combination inserted in the compound body of the instrument to increase the "power" of the objective and eye-piece.

*Immersion lenses* have lately attracted great attention, though they were made by Amici many years since. The objective is immersed in water, — that is, there is a film of water between the front of the objective and the object, or the thin glass covering it. The effect is a great increase of light, and better definition.

# REVIEWS.

THE ANIMAL NATURE OF SPONGES.[*] — Many opinions have been expressed with regard to the animal nature of the sponge, which has been considered as a plant by most authors, but nothing of a reliable or definite nature had appeared before a paper by Mr. Carter in the Annals and Magazine of Natural History, for April, 1857. In this paper it was first shown that the organized layer of the sponge was made up of single-

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[*] On the Spongiæ Ciliatæ as Infusoria Flagellata; or, Observations on the Structure, Animality, and Relationship of *Leucosolenia botryoides* Bowerbank. With two plates, and more than seventy-eight figures. By Professor H. James Clark, A. B., B. S. Memoirs of Boston Society of Natural History, June 20, 1866.